



Sandia  
National  
Labs

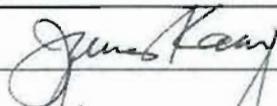
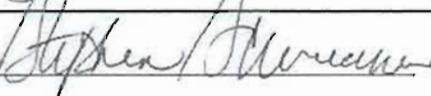
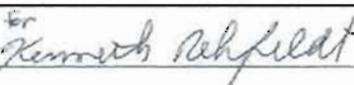
# Scientific Analysis/Calculation Administrative Change Notice

DOC.20070212.0001

QA: QA

Page 1 of 1

Complete only applicable items.

1. Document Number:	ANL-NBS-HS-000055	2. Revision:	00	3. ACN:	02
4. Title:	Data Analysis for Infiltration Modeling: Development of Soil Units and Associated Hydraulic Parameter Values				
5. No. of Pages Attached:	18 12	ACN 2/12/07			
6. Approvals:					
Preparer:	Charles Haukwa Print Name and Sign			02/05/2007 Date	
Checker:	James Kam Print name and sign			02/05/2007 Date	
QCS/Lead Lab QA Reviewer:	Stephen Schuermann Print name and sign			2/5/07 Date	
Responsible Manager:	Kenneth Rehfeldt for Stephanie Kuzio Print name and sign			2/5/2007 Date	
7. Affected Pages		8. Description of Change:			
4-4, 4-4a		1 <sup>st</sup> paragraph - incorporate DOE comment to replace DIRS 169734 with DIRS 177081.  (Note: Additional change bar from ACN 01)			
6-1		Table 6-1 - incorporate DOE comment to replace DIRS 169734 with DIRS 177081.			
6-22, 6-23		Editorial change: applied bold style to heading "Soil Unit 8: Bedrock" and "Soil Unit 10: Disturbed Ground".			
6-32, 6-32a		1 <sup>st</sup> paragraph - incorporate DOE comment to replace DIRS 169734 with DIRS 177081.  3 <sup>rd</sup> paragraph – insert comma after (PNNL).			
6-58		1 <sup>st</sup> paragraph - incorporate DOE comment to replace DIRS 169734 with DIRS 177081.  (Note: Additional change bar from ACN 01)			
6-61		Table 6-14 – incorporate DOE comment to use exact source values. Table 6-14, last column 1 - incorporate checker comment to replace -0.0177544 with 0.0177544. Table 6-14 – incorporate checker comment to change footnote designators and add footnote designators in the table body.			
6-76		Figure 6-22 caption – incorporate DOE comment to add minus sign to "(61,200 cm)".			
8-1, 8-4		Reference list – incorporate DOE comment to replace DIRS 169734 with DIRS 177081.			
4-4, 4-4a, 6-1, 6-32, 6-32a, 6-58		Incorporate checker comment to include a reference that shows distances between YM Sites 1, 2, 3 and 6 (Figure 4.1-1 added to text citations for DIRS 177081).  (Note: Additional change bar from ACN 01)			

**Extent to which the data demonstrate the properties of interest:** Data provided in the properties report (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B) include saturated hydraulic conductivity, soil moisture at a range of matric potential, and moisture retention curve fitting parameters that would be used as input to several infiltration modeling approaches including the one developed for Yucca Mountain. These data are developed from soil and sediment samples collected at Hanford where soils have developed under arid climatic conditions similar to that of Yucca Mountain. The average annual precipitation at Hanford is about 17.3 cm/yr (DOE 2001 [DIRS 177079], Section 3.2) compared to an average of 19.9 cm/yr for Yucca Mountain Meteorological Stations which are within 4 km to 5 km of the repository (YM Site 1, YM Site 2, YM Site 3, and YM Site 6 (SNL 2006 [DIRS 177081], Figure 4.1-1 and Table 7.1-1)).

Hanford sediments have organic carbon content below 0.5 wt% (Truex et al. 2001 [DIRS 177078], Section 2.3.1.2). Organic carbon content in agricultural areas of Nye County range from about 0.006% to 0.70% (USDA 2006 [DIRS 176439]). Soil textural information provided in the properties report (Khaleel and Freeman 1995 [DIRS 175734], Appendix A) is directly comparable to soils information in DTNs: MO0512SPASURFM.002 [DIRS 175955], GS031208312211.001 [DIRS 171543], and GS000383351030.001 [DIRS 148444].

The soil depositional processes at Yucca Mountain compared to those at Hanford include some differences, which can contribute to differences in grain shape and soil structure. Large-scale fluvial processes dominate Hanford soil and sediments resulting in more-rounded particles and single-grain structure. Small-scale fluvial processes and eolian (Soil Unit 6) are the dominant processes at Yucca Mountain, resulting in less-rounded particles with more angular fragments. Soils of fluvial origin associated with Soil Units 1 through 4 (stream and alluvial fan material) cover over 40% of the infiltration model area. There is an eolian component that has accumulated on these surfaces through time, which is concentrated in the upper 0.5 to 1 m of the soil profile. Deposits representing eolian source material are mapped over only 4.8% of the area (Soil Unit 6). The dominant surficial deposit (54% of the model area; Soil Units 5, 7, and 9) is colluvium. The colluvium consists of rock fragments of parent material that have been separated from the underlying intact bedrock through weathering processes. Colluvium, however, by definition, does not remain in situ, but moves or has moved, or both, downslope through gravitational processes. The fine-grained component of colluvial soils is interpreted to be due to the influx of eolian material.

There are depositional mode differences between the YMP soils and Hanford soils and sediments; the differences in the associated hydraulic parameters, however, are not quantified because there are no site-specific hydraulic data for Yucca Mountain. Such differences contribute to an overall uncertainty, captured by the development of descriptive statistics for each hydraulic parameter that includes the parameter mean and standard deviations (Section 6.3).

**Prior uses of the data:** Similar applications of data (Khaleel and Freeman 1995 [DIRS 175734]) include the use of hydraulic parameter values extracted from data for the vadose zone flow and transport modeling by Kincaid et al. (1998 [DIRS 176155], Section 4.1.2.1.2 and Table 4.7). Kincaid et al. (1998 [DIRS 176155]) were prepared to provide an estimate of the cumulative radiological impacts of waste and disposal actions at Hanford. Soil hydraulic parameter data (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B) were used as

direct input into vadose zone flow and transport models that were integral to developing cumulative impacts (Kincaid et al. 1998 [DIRS 176155], Section 4.1.2.1.2 and Table 4.7).

## 6. SCIENTIFIC ANALYSIS DISCUSSION

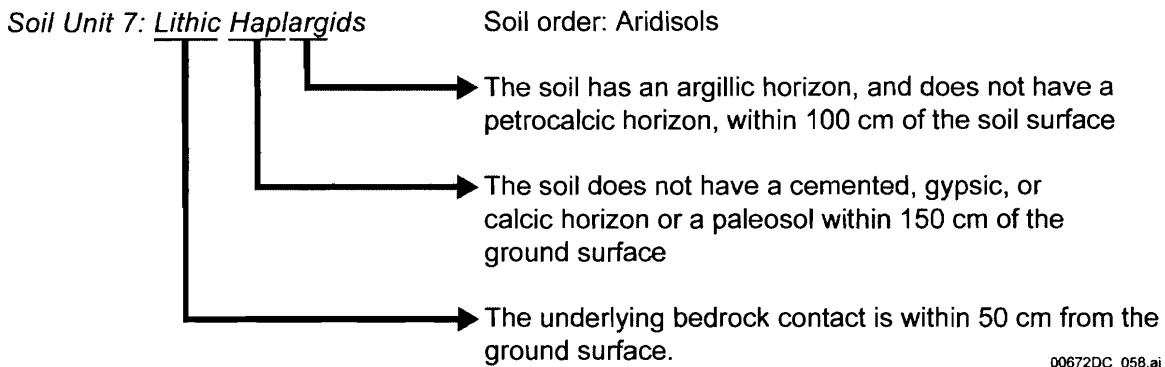
### 6.1 INTRODUCTION

This section documents the technical approach used to verify the distribution of soil units across the Yucca Mountain infiltration model area and to develop hydraulic parameter values and associated statistics for those soil units. The spatial distribution of soil units and their hydraulic properties are input to the analysis of net infiltration from precipitation at Yucca Mountain. The definition of the soil units is based on mapping of surficial deposits in the Yucca Mountain area. DTN: GS960408312212.005 [DIRS 146299] groups approximately 40 surficial deposit map units into 10 soil units to create a surficial properties/hydrologic properties map for input into subsequent infiltration modeling. Rationale for grouping surficial mapping units into soil units was not provided in DTN: GS960408312212.005 [DIRS 146299]. Hence, the definition of the soil units is reviewed to assess the appropriateness of the grouping (Section 6.2) and rationale is provided for the grouping.

Section 6.3 discusses the development of hydraulic parameters for the Yucca Mountain soil units. This analysis uses empirical data available for soil units, including grain-size distribution and fraction of rock fragments. These data were derived from laboratory analysis of soil samples collected from Yucca Mountain soil units (DTNs: GS031208312211.001 [DIRS 171543], MO0512SPASURFM.002 [DIRS 175955], and GS000383351030.001 [DIRS 148444]). Representative hydraulic parameter values of each of the soil units are developed by matching the texture of samples from Yucca Mountain soil units to similar soil textures in an analogous site database (Khaleel and Freeman 1995 [DIRS 175734]). In the analogous site database, hydraulic parameters have been determined for soil samples that are characterized by particle size data (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B). Technical inputs used directly in the calculation of the hydraulic parameters for the Yucca Mountain soil units are listed in Table 4-1. Indirect inputs of corroborative or supporting information for this analysis are provided as Table 6-1. Soil unit distributions, hydraulic parameters, and associated statistics developed herein include spatial variability and are only intended for use as input to an infiltration model.

Table 6-1. Indirect Inputs

<b>Technical Product Input Source</b>	<b>Specifically Used From</b>	<b>Specifically Used In</b>	<b>Input Description</b>
10 CFR Part 63 [DIRS 176544]	Entire	Section 4.2	Description of general requirements to be satisfied by the TSPA
ARCINFO [DIRS 157019]	Entire	Section 1	General reference to software used in analysis
Bamberg [DIRS 127392]	Figures 1 and 2	Sections 5.5 and 6.3.	Background for development of permanent wilting point for several Mojave Desert shrubs
SNL 2006 [DIRS 177081]	Figure 4.1-1 and Table 7.1-1	Sections 4.1.3, 6.3, and 6.4.4	Location of weather stations at Yucca Mountain and Average annual rainfall for Yucca Mountain area
BSC 2005 [DIRS 175539]	Table A-1	Section 2	Classification of safety category for natural barriers



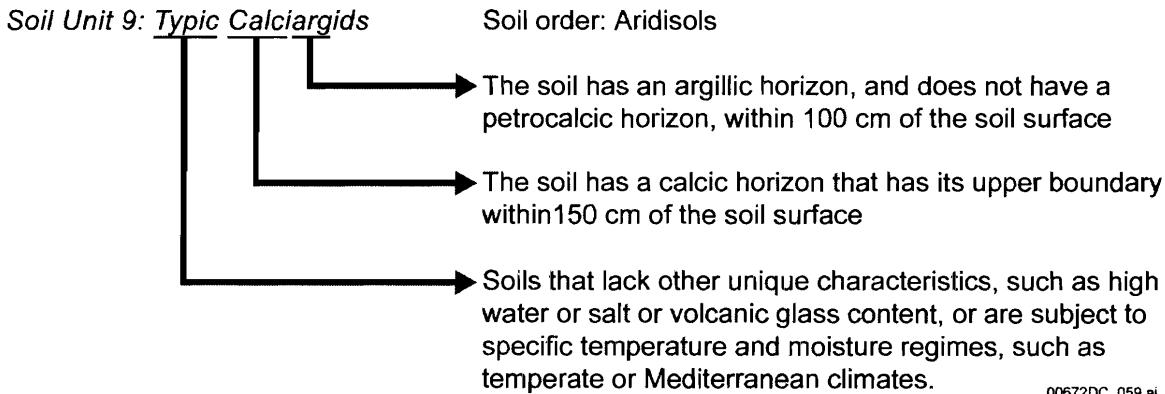
Sources: Keefer et al. 2004 [DIRS 173899], Chapter 2; Swan et al. 2001 [DIRS 158784], pp. 8 to 21.

Figure 6-8. Description of Soil Unit 7: Lithic Haplargids

Soil Unit 7 occurs in about 1% of the map area (Table 6-3) and is confined to vegetated ridgetops in the northernmost part of the infiltration model area (Figure 6-1; Table 6-4, Surficial Map Unit rc). It is a thin mantle, generally less than 1 m thick, of an angular gravel diamicton composed of tabular slabs of the underlying Tiva Canyon bedrock mixed with a sandy clay loam soil matrix. The fine-grained matrix is attributed to an eolian origin. A tightly packed desert pavement has developed on the relatively level surfaces (DTN: GS940108315142.005 [DIRS 160345]).

### Soil Unit 8: Bedrock

Soil Unit 8 comprises 0.3% of the map area (Table 6-3) and defines exposed bedrock (Table 6-2). Hydraulic properties for exposed bedrock are developed in *Data Analysis for Infiltration Modeling: Bedrock Saturated Hydraulic Conductivity Calculation* (BSC 2006 [DIRS 176355]) and are not discussed further in this analysis.



Sources: Keefer et al. 2004 [DIRS 173899], Chapter 2; Swan et al. 2001 [DIRS 158784], pp. 8 to 21.

Figure 6-9. Description of Soil Unit 9: Typic Calciargids

Vegetated colluvial deposits at the toes of hillsides have been grouped into Soil Unit 9 (Table 6-2). This unit defines about 6% of the model area (Table 6-3) and consists of interbedded colluvium and debris flow deposits, grading to and interbedded with alluvium on upper fan surfaces (Table 4, Surficial Map Unit cf). Reported thickness ranges from 0.5 to 3 m and the extent of soil development observed is comparable to that of Soil Units 3 and 4.

### **Soil Unit 10: Disturbed Ground**

Soil Unit 10 comprises 1% of the map area (Table 6-3) and defines disturbed ground (Table 6-2) such as roads, drilling pads, and construction areas. As shown in Figure 6-1, most of the disturbed soils (Soil Unit 10) are associated with Soil Units 1, 2, and 3. The hydraulic properties assigned to Soil Unit 10 are properties of the soils from which they are derived (Section 6.3) and vary by location depending on the underlying soil unit. No properties unique to Soil Unit 10 were developed in this analysis.

#### **6.2.4 Corroboration with Other Soil Surveys**

Two other soil surveys have been completed for portions of the Yucca Mountain infiltration model area. In a 1989 soil survey, the distribution of four soil units was shown at a small scale for Yucca Mountain (Resource Concepts 1989 [DIRS 103450], Figure 2). In 2004, a soil survey for the southwestern portion of Nye County was published (USDA 2004 [DIRS 173916]), hereafter referred to as the 2004 soil survey. The Busted Butte quadrangle of this survey covers the southwest portion of Yucca Mountain, which is administered by the Bureau of Land Management. The 2004 soil survey did not map the two-thirds of the Yucca Mountain infiltration model area that is administered by Nellis Air Force Base or has been set-aside for the Nevada Test Site. The mapping of soil units in the 1989 and 2004 soil surveys (Resource Concepts 1989 [DIRS 103450]; USDA 2004 [DIRS 173916]) are compared with the mapping of soil units in DTN: GS960408312212.005 [DIRS 146299] (Figure 6-1), as shown in Figure 6-10.

The approach used by these two alternative soil surveys is equivalent to that used by DTN: GS960408312212.005 [DIRS 146299] in that the soils are identified by USDA taxonomic nomenclature and are, thus, subdivided by characteristics such as depth to bedrock, the presence or lack thereof of a duripan with depth, or observable pedogenic products. Soil series distribution, USDA taxonomic names, and equivalent soil units identified herein are listed in Table 6-5. Some of the taxonomic names used in the 1989 soil survey (Resources Concepts 1989 [DIRS 103450]) predate the more recent nomenclature used in DTN: GS960408312212.005 [DIRS 146299] and in the 2004 soil survey (USDA 2004 [DIRS 173916]); Table 6-5 provides equivalent names.

In general, the mapping of soil units shown in Figure 6-1 is more detailed than shown in other surveys. Also, the soil units used in the 2004 soil survey (USDA 2004 [DIRS 173916]) were applied to a much larger geographical area than just Yucca Mountain and, thus, may represent a characterization that accommodates a wider range of features than those observed in the infiltration model area. For example, one of the most common soil types is described as developed in lacustrine deposits, which do not occur in the infiltration model area, but do occur further to the west in the Amargosa Valley area.

compared to an average of 19.9 cm/yr for Yucca Mountain Meteorological Stations which are within 4 km to 5 km of the repository (YM Site 1, YM Site 2, YM Site 3, and YM Site 6 (SNL 2006 [DIRS 177081], Figure 4.1-1 and Table 7.1-1)). Hanford sediments have organic carbon content below 0.5 wt% (Truex et al. 2001 [DIRS 177078], Section 2.3.1.2). Organic carbon content in agricultural areas of Nye County range from about 0.006% to 0.70% (USDA 2006 [DIRS 176439]).

The analogous site database (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B) contains documented information on moisture retention, particle-size distribution,  $K_{sat}$  for 183 samples, sample collection methods, laboratory equipment, and laboratory procedures. Additionally, for samples that contain gravel, the moisture retention and  $K_{sat}$  data were corrected to account for the gravel content (Khaleel and Freeman 1995 [DIRS 175734], p. iii).

### 6.3.1 Parameters and Analogous Site Parameter Data Base

The analogous site database (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B) includes information on soil moisture retention, the parameters  $\theta_r$ ,  $\theta_s$ ,  $\alpha$ , and  $n$  (van Genuchten et al. 1991 [DIRS 108810]), particle-size distribution, and  $K_{sat}$  for 183 samples (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B). Soil samples were collected primarily in conjunction with cable tool drilling activities. In most cases, split-spoon coring techniques were used to obtain samples. Laboratory analyses were performed at the Westinghouse Hanford Company Geotechnical Laboratory (GEL) or at the Pacific Northwest National Laboratory (PNNL), one of the DOE national laboratories. Particle-size distributions were determined on the less than 0.075 mm size fraction using a hydrometer. Dry sieving was used on the size fraction greater than 0.075 mm to less than 2 mm. At the GEL, moisture retention data were obtained using Tempe cells from saturation to -1,000 cm and the pressure plate extraction method for pressure heads from -1,000 to -15,000 cm. Constant head permeameter apparatus and methodology were used to determine  $K_{sat}$  (Khaleel and Freeman 1995 [DIRS 175734], Section 2.0).

Three test methods were used at the PNNL to determine moisture retention data: (1) the hanging water column method, (2) the pressure plate extraction method, and (3) the vapor equilibrium method. The  $K_{sat}$  was determined using a falling head permeameter (Khaleel and Freeman 1995 [DIRS 175734], Section 2.0). The procedures used at the GEL before 1993 produced the primary drainage curve, whereas procedures used at the PNNL produced the main drainage curve. In the properties report (Khaleel and Freeman 1995 [DIRS 175734], Sections 2.0 and 3.4 and Appendices A and B) an adjustment to the pre-1993 GEL generated data was applied to obtain the main drainage curve from the primary drainage curve (PDC).

Moisture retention and  $K_{sat}$  data in the analogous site database (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B) are laboratory-measured values that were first corrected, if necessary, for gravel content (Khaleel and Freeman 1995 [DIRS 175734], Sections 3.2, 3.3, and 5.1). Some data from the GEL, before 1993, also required adjustment to obtain the main drainage curve from the PDC as previously noted. Moisture retention data from the Tempe cell or hanging water column experiments for each individual sample were combined with the pressure-plate and vapor equilibrium data (Khaleel and Freeman 1995 [DIRS 175734], Section 5.1) to estimate the van Genuchten parameters  $\theta_r$ ,  $\theta_s$ , and  $\alpha$  and  $n$  (van Genuchten et al.

1991 [DIRS 108810]). The van Genuchten parameters were then fitted to the moisture retention data.

sample hydraulic parameter values. The analogous site database (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B) is complete with respect to grain-size distribution and gravel content, but does not include any of the other parameters useful for the development of PTFs, such as bulk density, porosity, organic content, or plasticity index. The soils and sediments identified in the analogous site database (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B) were collected at Hanford, an arid region of eastern Washington. The soils at Hanford have developed under arid climatic conditions similar to those at Yucca Mountain. The average annual precipitation at Hanford is about 17.3 cm/yr (DOE 2001 [DIRS 177079], Section 3.2) compared to an average of 19.9 cm/yr for Yucca Mountain Meteorological Stations which are within 4 km to 5 km of the repository (YM Site 1, YM Site 2, YM Site 3, and YM Site 6 (SNL 2006 [DIRS 177081], Figure 4.1-1 and Table 7.1-1)). Hanford sediments have organic carbon content below 0.5 wt% (Truex et al. 2001 [DIRS 177078], Section 2.3.1.2). Organic carbon content in agricultural areas of Nye County range from about 0.006% to 0.70% (USDA 2006 [DIRS 176439]).

The soils at Hanford contain less organic material than soils developed under wetter conditions, which is also true of the soils at Yucca Mountain. The soil depositional processes at Yucca Mountain compared to those at Hanford include some differences that can contribute to differences in grain shape and soil structure. Large-scale fluvial processes dominate Hanford soil and sediments resulting in more-rounded particles and single-grain structure. Small-scale fluvial processes and eolian (Soil Unit 6) are the dominant processes at Yucca Mountain, resulting in less-rounded particles with more angular fragments (Section 6.2). Soils of fluvial origin associated with Soil Units 1 through 4 (stream and alluvial fan material) cover over 40% of the infiltration model area. There is an eolian component that has accumulated on these surfaces through time, which is concentrated in the upper 0.5 m of the soil profile (Table 6-4). Deposits representing eolian source material are mapped over only 4.8% of the area (Soil Unit 6).

The dominant surficial deposit (54% of the model area; Soil Units 5, 7, and 9) is colluvium. The colluvium consists of rock fragments of parent material that have been separated from the underlying intact bedrock through weathering processes. Colluvium, however, by definition, does not remain in situ, but moves or has moved, or both, downslope through gravitational processes. The fine-grained component of colluvial soils is interpreted to be due to the influx of eolian material. There are depositional mode differences between the YMP soils and Hanford soils and sediments; the differences in the associated hydraulic parameters, however, are not quantified because there are no site-specific hydraulic data for Yucca Mountain. Such differences contribute to an overall uncertainty, captured by the development of descriptive statistics for each hydraulic parameter, which include the parameter mean and standard deviations.

Overall, the literature review suggests that the matching approach, using the analogous site database (Khaleel and Freeman 1995 [DIRS 175734], Appendices A and B), would be less uncertain if additional data, such as bulk density, were available for Yucca Mountain and for Hanford.

This result is consistent with a recharge study at the Glassboro Study Area, New Jersey, by the USGS in which it found that ROSETTA lead to unreasonably high recharge estimates, primarily due to the over-prediction of saturated hydraulic conductivity (USGS 2003 [DIRS 177192], p. 2). The study used data from six locations in southern New Jersey that appear to have steady-state flow conditions and five hydraulic property prediction and parameterization techniques were evaluated for recharge estimation. The unsaturated zone at the Glassboro Study Area, New Jersey, is mainly sand to sandy loam in texture. It is not clear why ROSETTA may be over-predicting  $K_{sat}$ ; the same study found that water retention was predicted relatively well by ROSETTA (USGS 2003 [DIRS 177192], p. 2). Figures 6-18 and 6-19 provide comparisons between the three methods based on arithmetic mean values and geometric mean values of  $K_{sat}$ , respectively. When comparing the results based on the arithmetic mean values, the large values dominate and the three methods appear to result in very similar  $K_{sat}$  values. Small  $K_{sat}$  values dominate with comparison of the geometric mean. This comparison reveals that the analogous site method and the Rawls and Brakensiek method (Rawls and Brakensiek 1985 [DIRS 177045]) have good agreement and, as previously noted, the ROSETTA results are consistently larger; the smaller the bar the larger the  $K_{sat}$  value.

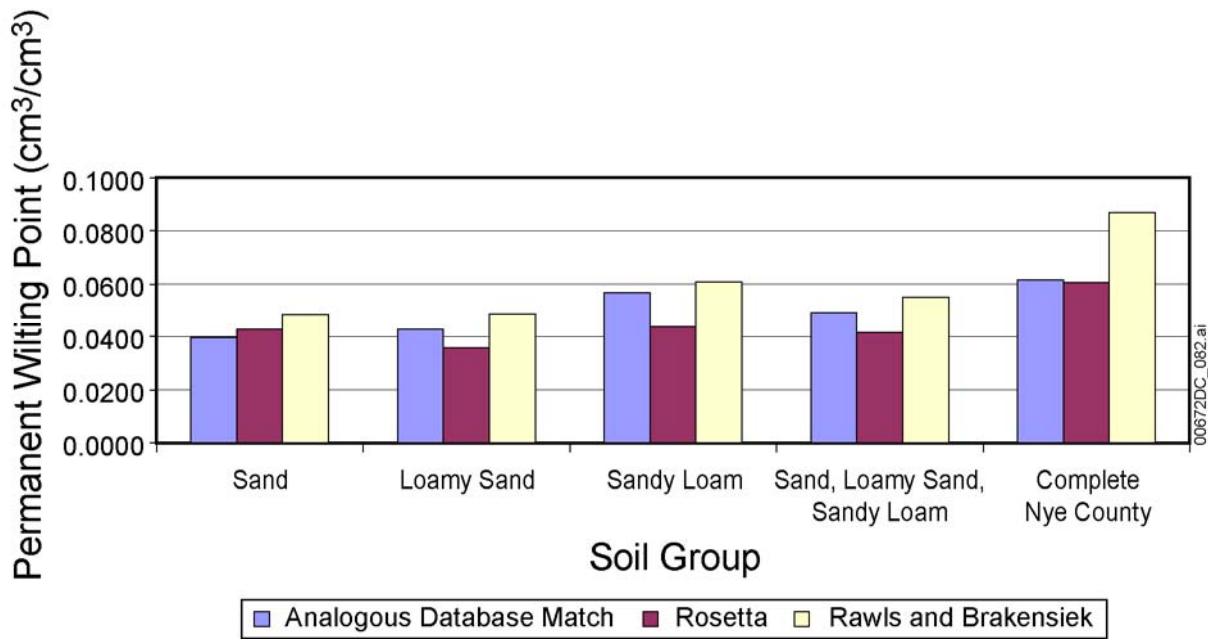
Table 6-14. Rawls and Brakensiek Regression Constants

Term	Natural Log Saturated Hydraulic Conductivity ( $K_{sat}$ ) Ln[cm/hr]	Residual Water Content ( $\theta_r$ ) [cm <sup>3</sup> /cm <sup>3</sup> ]	Natural Log (1/ $\alpha$ ) Ln[cm]	Natural Log N -dimensionless
(Constant)	-8.96847	-0.0182482	5.3396738	-0.7842831
S	-	0.00087269 <sup>a</sup>	-	0.0177544
C	-0.028212	0.00513488	0.1845038	-
$\theta_s$	19.52348	0.02939286	-2.48394546	-1.062498
$S^2$	0.00018107	-	-	-0.00005304
$C^2$	-0.0094125	-0.00015395 <sup>a</sup>	-0.00213853	-0.00273493
$\theta_s^2$	-8.395215	-	-	1.11134946
SC	-	-	-	-
$S\theta_s$	0.077718	-0.0010827	-0.0435649	-0.03088295
$C\theta_s$	-	-	-0.61745089	-
$S^2C$	0.0000173	-	-0.00001282	-0.00000235
$C^2\theta_s$	0.02733	0.00030703 <sup>a</sup>	0.00895359	0.00798746
$S^2\theta_s$	0.001434	-	-0.00072472 <sup>a</sup>	-
$SC^2$	-0.0000035	-	0.0000054	-
$C\theta_s^2$	-	-0.0023584	0.50028060	-0.00674491
$S^2\theta_s^2$	-0.00298	-	0.00143598	0.00026587
$C^2\theta_s^2$	-0.019492	-0.00018233 <sup>a</sup>	-0.00855375	-0.00610522

Source: Carsel and Parrish 1988 [DIRS 147295], Figure 1.

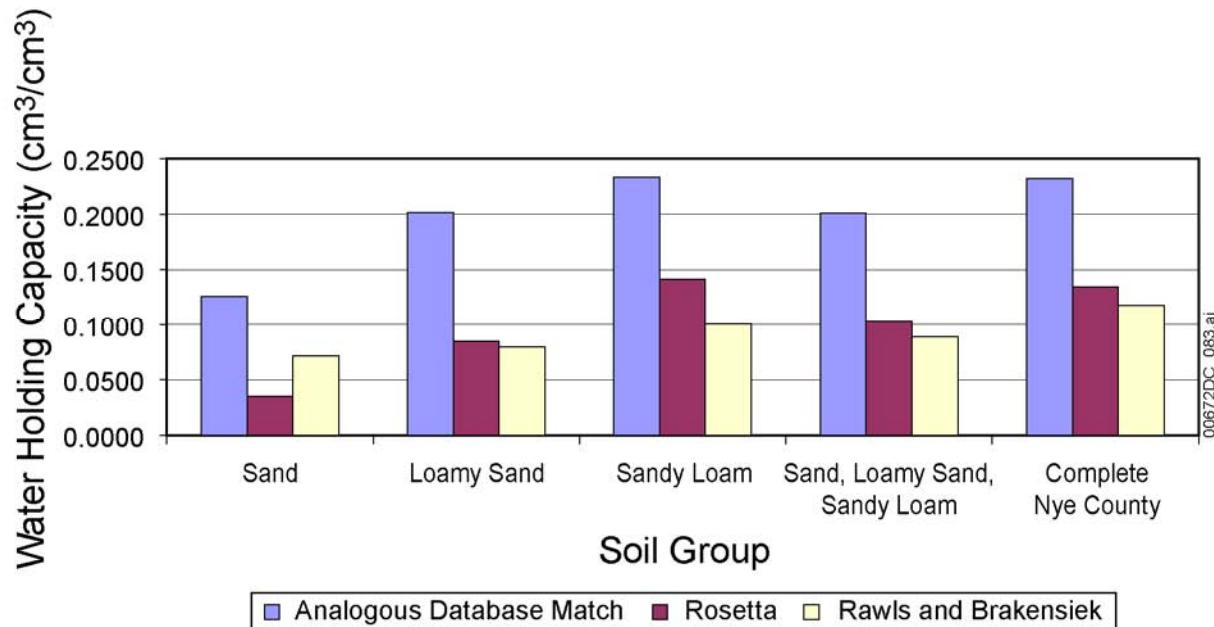
NOTE: <sup>a</sup>Corrected coefficients for  $\theta_r$  and 1/ $\alpha$  are from NUREG/CR-6565 (Meyer et al. 1997 [DIRS 176004], p. 5).

This table uses exact source values.



Source: DTN: MO0608SPANYECT.000, *NyeCounty\_MethodCorroboration\_August1\_2006.xls*, worksheet 'CompareMeans'.

Figure 6-22. Mean Permanent Wilting Point at -60 Bar (-61,200 cm) for Three Pedotransfer Function Methods Using Nye County Data



Source: DTN: MO0608SPANYECT.000, *NyeCounty\_MethodCorroboration\_August1\_2006.xls*, worksheet 'CompareMeans'.

Figure 6-23. Mean Water Holding Capacity at -0.10 Bar (-102 cm) Field Capacity for Three Pedotransfer Function Methods Using Nye County Data

## 8. INPUTS AND REFERENCES

### 8.1 DOCUMENTS CITED

- 127392 Bamberg, S.A.; Kleinkopf, G.E.; Wallace, A.; and Vollmer, A. 1975. "Comparative Photosynthetic Production of Mojave Desert Shrubs." *Ecology*, 56, (3), 732-736. Tempe, Arizona: Ecological Society of America. TIC: 242300.
- 175944 Brakensiek, D. L. and Rawls, W. J. 1994. "Soil Containing Rock Fragments: Effects on Infiltration." *Catena*, 23, 99-110. New York, New York: Elsevier. TIC: 257971.
- 170007 BSC (Bechtel SAIC Company) 2004. *Simulation of Net Infiltration for Present-Day and Potential Future Climates*. MDL-NBS-HS-000023 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041109.0004.
- 175539 BSC 2005. *Q-List*. 000-30R-MGR0-00500-000-003. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050929.0008.
- 176355 BSC 2006. *Data Analysis for Infiltration Modeling: Bedrock Saturated Hydraulic Conductivity Calculation*. ANL-NBS-HS-000054 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20060710.0001.
- 177492 BSC 2006. *Technical Work Plan for: Infiltration Model Assessment, Revision, and Analyses of Downstream Impacts*. TWP-NBS-HS-000012 REV 02. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20060831.0006.
- 147295 Carsel, R.F. and Parrish, R.S. 1988. "Developing Joint Probability Distributions of Soil Water Retention Characteristics." *Water Resources Research*, 24, (5), 755-769. Washington, D.C.: American Geophysical Union. TIC: 247697.
- 176383 Cornelis, W.M.; Ronsyn, J.; Van Meirvenne, M.; and Hartmann, R. 2001. "Evaluation of Pedotransfer Functions for Predicting the Soil Moisture Retention Curve." *Soil Science Society of America Journal*, 65, 638-648. Madison, Wisconsin: Soil Science Society of America. TIC: 258085.
- 177039 Cronican, A.E. and Gribb, M.M. 2004. "Hydraulic Conductivity Prediction for Sandy Soils." *Ground Water*, 42, (3), 459-464. Westerville, Ohio: National Ground Water Association. TIC: 258368.

- 177511 Nemes, A.; Rawls, W.J.; and Pachepsky, Y.A. 2006. "Use of the Nonparametric Nearest Neighbor Approach to Estimate Soil Hydraulic Properties." *Soil Physics*, 327-336. Madison, Wisconsin: Soil Science Society of America. TIC: 258543.
- 163274 NRC (U.S. Nuclear Regulatory Commission) 2003. *Yucca Mountain Review Plan, Final Report*. NUREG-1804, Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. TIC: 254568.
- 177026 Odening, W.R.; Strain, B.R.; and Oechel, W.C. 1974. "The Effect of Decreasing Water Potential on Net CO<sub>2</sub> Exchange of Intact Desert Shrubs." *Ecology*, 55, (5), 1086-1095. Ithaca, New York: Ecological Society of America. TIC: 258305.
- 177045 Rawls, W.J. and Brakensiek, D.L. 1985. "Prediction of Soil Water Properties for Hydrologic Modeling." *Watershed Management in the Eighties, Proceedings of the Watershed Management Symposium Held in Conjunction with the ASCE Convention, Denver, Colorado, April 30-May 1, 1985*. Jones, E.B. and Ward, T.J., eds. Pages 293-299. New York, New York: American Society of Civil Engineers. TIC: 258369.
- 103450 Resource Concepts 1989. *Soil Survey of Yucca Mountain Study Area, Nye County, Nevada*. NWPO EV 003-89. Carson City, Nevada: Resource Concepts. TIC: 206227.
- 177199 Schaap, M.G.; Leij, F.J.; and van Genuchten, M.Th. 1998. "Neutral Network Analysis for Hierarchical Prediction of Soil Hydraulic Properties." *Soil Science Society of America Journal*, 62, (4), 847-855. Madison, Wisconsin: Soil Science Society of America. TIC: 258402
- 176006 Schaap, M.G.; Leij, F.J.; and van Genuchten, M. Th. 2001. "ROSETTA: A Computer Program for Estimating Soil Hydraulic Parameters with Hierarchical Pedotransfer Functions." *Journal of Hydrology*, 251, (3-4), 163-176. New York, New York: Elsevier. TIC: 258401.
- 103636 Smith, S.D.; Monson, R.K.; and Anderson, J.E. 1997. *Physiological Ecology of North American Desert Plants*. New York, New York: Springer-Verlag. TIC: 242260.
- 177081 SNL (Sandia National Laboratories) 2006. *Data Analysis for Infiltration Modeling: Extracted Weather Station Data Used to Represent Present-Day and Potential Future Climate Conditions in the Vicinity of Yucca Mountain*. ANL-MGR-MD-000015 REV 00. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20070109.0002.
- 158784 Swan, F.H.; Wesling, J.R.; Angell, M.M.; Thomas, A.P.; Whitney, J.W.; and Gibson, J.D. 2001. *Evaluation of the Location and Recency of Faulting Near Prospective Surface Facilities in Midway Valley, Nye County, Nevada*. Open-File Report 01-55. Denver, Colorado: U.S. Geological Survey. TIC: 251592.